A PRELIMINARY STUDY OF THE FINER STRUCTURE OF ARCELLA

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THIS study of Arcella is based upon two species, *Arcella vulgaris* Ehrenberg and *Arcella mitrata* Leidy. The structure of the test in Arcella is usually described as given by Leidy ("Fresh-water Rhizopods of North America," *U. S. Geol. Surv. Territories*, vol. 12, p. 167): "Composed of a more or less translucent or transparent chitinoid membrane, with a minutely hexagonal cancellated

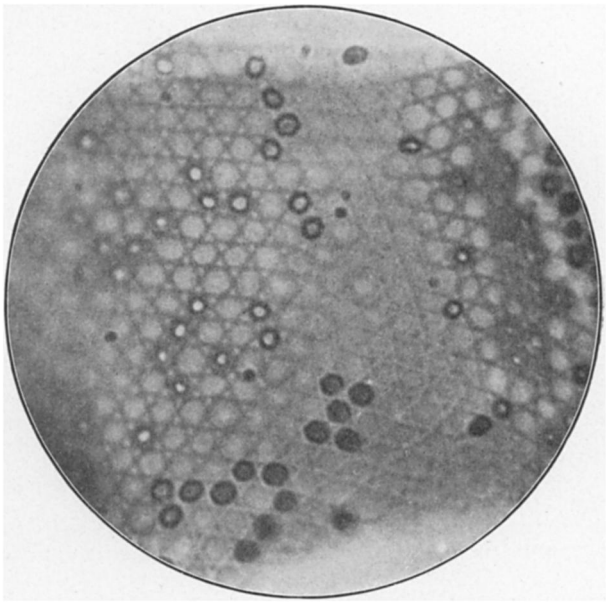

FIG. 1.— *Arcella vulgaris* Ehrenberg. ×3100. Showing many air bubbles in the cancelli and the structure of the network. Photomicrograph, $\frac{1}{12}$ in. oil-immersion objective.

structure." Closer study of the test of these two species with high magnification shows further complication of this structure, not shown at all in the "honeycomb" figure given by Leidy, Pl. 27,

Fig. 35. Moreover, as will be shown later, the arrangement of the hexagons is on an entirely different plan from that shown in Leidy's figure and those of other authors.

Hertwig and Lesser (*Arch. f. mikr. Anat.*, vol. 10, suppl., 1874) after reviewing and rejecting the conclusions of Dujardin, Ehrenberg, Claparède, Carter, and Wallich go rather fully into the more minute structure of the test and reach a positive conclusion as follows (p. 96): "Ihrer feineren Structur nach besteht die Schale aus zwei Platten, einer äusseren und einer inneren, welche einan-

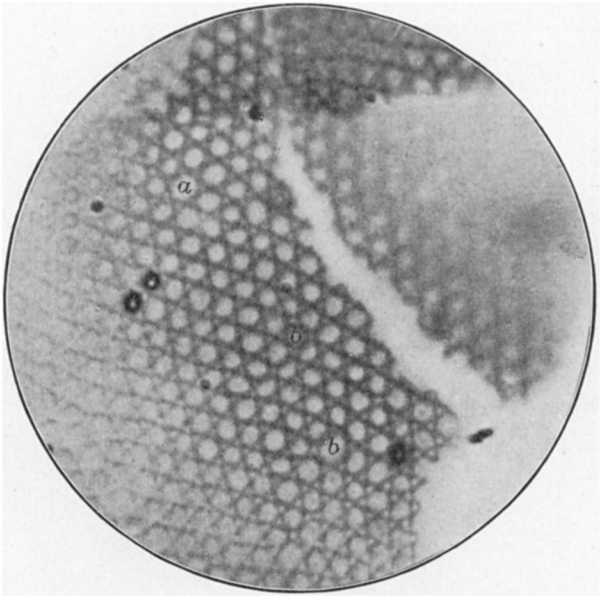

FIG. 2.— *Arcella vulgaris* Ehrenberg. ×3100. Showing the introduction of columns of plates and resulting change in the number of sides of the plates. *a*, heptagonal plate; *b*, *b*, irregularities with more than one column initiated.

der parallel gelagert sind und durch ein bienenwabenartiges, hexagonale Figuren bildendes Fachwerk vereint werden."

Hertwig and Lesser, by treatment of the test with sodium carbonate and acetic acid induced the formation of bubbles of carbonic-acid gas in the cancelli, which they considered closed chambers. In our specimens many bubbles of air were introduced into the cancelli with the greatest ease in the following manner. From about the entire test, under low power, the water was

drawn away until its level was so reduced that air reached the specimen. Bubbles at once formed in some of the cancelli and were present after dehydrating, clearing, tearing in pieces, and mounting in balsam or styrax. Many of these air bubbles are seen in Fig. 1, and a few are scattered about in Fig. 2. The ready entrance of air to form bubbles in the cancelli hardly seems to bear out the view that there are two thin plates, with the cancellated network lying between, as Hertwig and Lesser thought. If there were two membranes, it would be impossible, by the simple method adopted in this work, to cause air bubbles to form in the closed chambers lying between them. That there is but one membrane is very strongly indicated by the present study.

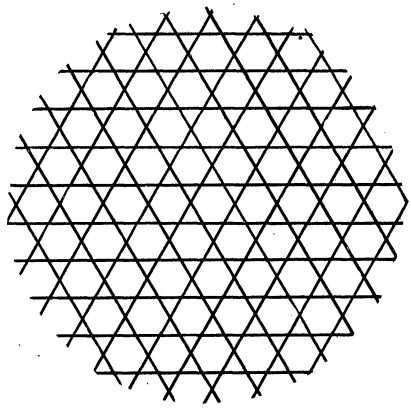

FIG. 3.— Diagrammatic representation of the structure of the upper surface of the network.

The next thing to determine was the position of the single membrane, whether it is on the outer or the inner side of the network. In the introduction of air bubbles the specimens were placed with the mouth-opening downward, the shell cavity being filled with water. At no time was the water allowed to become low enough to permit air to enter the mouth. In this manner only the upper surface was exposed, and no air could have entered the cancelli from the inside. Moreover, had air entered the shell cavity, it would at once have become evident as a large air bubble at the upper part of this cavity. The introduction of air having been thus controled, we conclude that the bubbles formed on the outside of the membrane, and therefore that the raised pattern or network projects externally.

The form of this network, as has been said, is radically unlike the honeycomb structure heretofore assigned to it. It is, to be sure, hexagonal in its main features, but the arrangement of the hexagonal areas is not at all what it has been represented. In the honeycomb arrangement the hexagons have sides in common.

In the Arcella test the hexagons have no sides in common. Instead, the hexagonal areas are so placed that the three adjacent sides of three neighboring areas enclose a small triangular space. Just here we find a further complication of the structure. These interpolated triangles are not solid portions of the network, but themselves contain areoles of subtriangular outline. The density of the medium through which the light is transmitted seemed, with the best illumination obtainable, the same in the small triangular areoles as in the larger hexagonal areas. From this we concluded that the areoles are depressed areas in the network

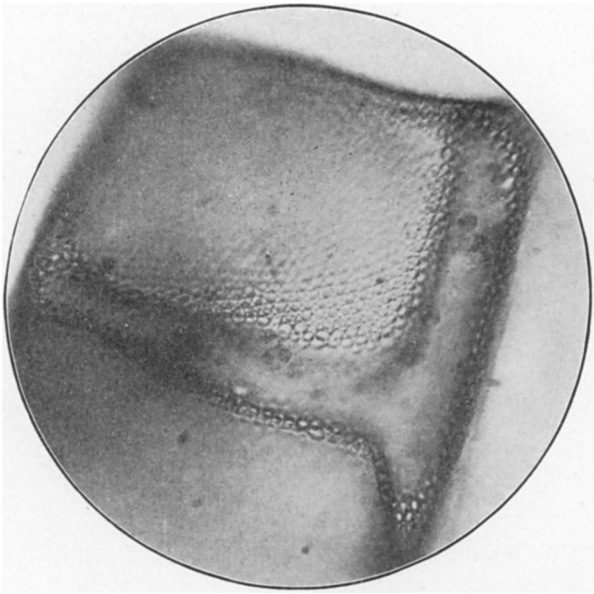

FIG. 4.— *Arcella mitrata* Leidy. ×1200. Photomicrograph showing structure of network like that in *A. vulgaris*.

similar, except in point of size and shape, to the hexagonal areas. Diagrammatically then, the network may be conceived as formed of straight lines in three sets of parallels, the lines of each set making an angle of sixty degrees with those of the two other sets (see diagram, Fig. 3). A comparison with the actual photographs, especially Fig. 2, seems to bear out this conclusion. That no air bubbles formed in the smaller spaces is natural, since the surrounding areas are much larger and of equal depth.

When the test was seen in optical section the reason for the view that there are two membranes was apparent, for the limiting upper edges of the raised network give the appearance of a wall covering in the top. This appearance seems to be merely the effect of refraction of light. The basal membrane may be clearly seen. In general the height of the raised network above the basal membrane is about equal to the width of the hexagonal areas.

Besides the further complication of structure in the test, another

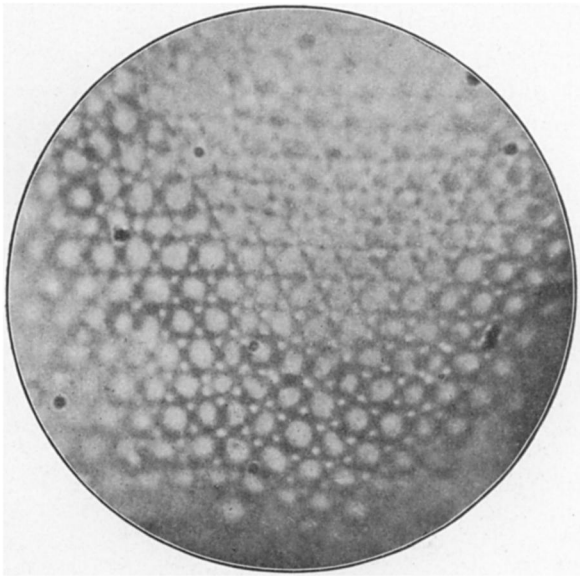

FIG. 5.— *Arcella mitrata* Leidy. ×3300. Photomicrograph of a portion of the specimen shown in Fig. 4, but much enlarged.

series of observations was made on the method of growth of the shell. As the animal increases in size toward the periphery, this increase must in some way be provided for. An increase in size of the hexagons might have been used but this would have been detrimental to the plan of structure. Instead of this, new columns of hexagonal areas are added or interpolated among the previous ones. By this means the plan of structure is not seriously interfered with. These new columns may be added in any of three directions conforming to the directions of the three sets of parallel lines already referred to.

In typical cases the new column of plates is initiated by an area having but five instead of six sides. To compensate for this mechanically, the preceding area has seven sides (Fig. 2, *a*). This equating method of heptagons and pentagons is typical whenever a single column is added in one spot. In certain cases, however, more than one column may originate, even with the same area, and then various irregularities are taken on (Fig. 2, *b*). In such cases, areas with but four sides are met with occasionally instead of the normal pentagonal areas. Besides this variation in the number of sides of the areas in different portions there seems to be a definite alternation of the columns, to the right and left of the axis in which they are added. This applies of course only to those columns added successively in one of the three directions mentioned above.

Altogether, the test of Arcella is far from the simple hexagonal structure figured by Leidy and other authors. Its complexities are worthy of further study and comparison with the tests of other rhizopods.